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Re-estimating the Annual Energy Outlook 2000 Forecast Using Updated Assumptions about the Internet Economy

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Introduction

In the period 1960 to 1996 the U.S. economy, measured by gross domestic product (in 1996 constant dollars), grew by an average 3.4 percent per year. In that same period, the nation's primary energy use grew 2.1 percent annually. In effect, the nation's energy intensity — in other words, the amount of energy needed to support the nation's economic activity — declined by an average rate of 1.3 percent per year. In the period 1996 to 1999, however, the nation's energy intensity declined at a rate of 3.4 percent annually. In absolute terms this is significantly greater than the 2.7 percent rate of decline that occurred in the "oil crisis" years of 1973 to 1986 (Energy Information Administration, 1999a and 1999b). What is remarkable about the trend in the last three years is that it has occurred in the absence of either price signals or major policy shifts.

The sharp decrease in the nation's energy intensity in the past three years has generated strong interest among analysts. Some analysts attribute the majority of the change to weather. A separate analysis by Laitner (1999), however, indicates that weather accounts perhaps for only 25 percent of the change in the nation's energy intensity. Boyd and Laitner (2000), suggest structural change as a major influence. Although three years of data are insufficient to establish a meaningful trend, the emerging evidence suggests that the rapidly growing influence of an information-based economy may account for at least a significant influence in the structural change (Romm, Rosenfeld, and Herrmann, 1999; and Laitner, 2000).

This paper is an attempt to evaluate the potential influence of the emerging "Internet economy" on the nation's forecasted energy use and related carbon emissions. Following this introduction, the next section outlines the broad structural changes that seem to be emerging as a result of the growth in the information and communication technologies sectors. The paper then discusses the reference case of the AEO2000 with particular attention to assumptions about the information-based economy. Next we discuss our assumptions with respect to how the AEO2000 reference case might change if it properly reflected the identified structural changes. Finally, we offer some conclusions with respect to our findings and outline potential directions for research.

The Emerging Information-Based Economy

The evidence is strong that the economy is changing as a result of the transition to an information-based economy. The information economy is now a leading economic driver within the United States. In the period 1990 through 1997, the rate of growth in the nation's economy averaged 2.6% per year. In contrast, the information and communication technology (ICT) sectors – not including Internet and electronic commerce sales – grew at an average rate of 13.5%, according to the Department of Commerce (Henry et al, 1999).

In testimony last year before Congress, Federal Reserve Board Chairman, Alan Greenspan, underscored the transition to the information economy. In his testimony, Chairman Greenspan noted: “Something special has happened to the American economy in recent years. An economy that twenty years ago seemed to have seen its better days, is displaying a remarkable run of economic growth that appears to have its roots in ongoing advances in technology. I have hypothesized on a number of occasions that the synergies that have developed, especially among the microprocessor, the laser, fiber-optics, and satellite technologies, have dramatically raised the potential rates of return on all types of equipment that embody or utilize these newer technologies. But beyond that, innovations in information technology – so-called IT – have begun to alter the manner in which we do business and create value, often in ways that were not readily foreseeable even five years ago” (Greenspan, 1999).

Further evidence suggests that this trend will continue. Forrester Research (1999), for example, projects that U.S. business to business electronic commerce will grow from $48 billion in 1998 to $1.3 trillion by 2003. Other estimates show similar levels of growth. Romm et al (1999) completed an extensive review of the potential energy impacts of the transition from a commodity-based economy to one based more on the flow of information. At the same time, Laitner (2000) reported a first approximation of what the structural change in the economy might mean if electronic commerce continues the current growth pattern. According to that preliminary analysis, there is a real possibility that these changes imply a somewhat smaller level of energy consumption compared to current economic projections. In other words, while energy use will grow, that growth will be somewhat slower than previous forecasts have indicated.

If the anticipated pattern of structural change continues to hold, then the information economy, together with more investments in energy efficient technologies, will benefit the nation’s air quality and the global climate while continuing to increase the nation’s overall competitiveness. Laitner’s “first approximation” indicated that mainstream projections of annual energy and carbon emissions by 2010 may be overestimated by about 5 quads and 80 million metric tons of carbon. This is about 5 percent lower than the most recent 2010 projections published by the Energy Information Administration EIA, 1999c). These results suggest the importance of measuring and evaluating the direct and indirect impact of IT sectors on the nation’s energy use (and the resulting emission of energy-related carbon emissions). Before we examine the issue further, we next describe the conventional forecast against which we will evaluate further changes in as a result of the structural changes.

A Conventional Forecast

In its release of the Annual Energy Outlook 2000 (EIA, 1999c), the Energy Information Administration indicated that the economy would grow at a rate of 2.2 percent annually between the years 1998 and 2020. As a result of this growth rate, and combined with a 1.0 percent decrease in the nation’s energy intensity, the nation’s energy use might be expected to increase from 95 quads in 1998 to 121 quads in 2020, an annual growth rate of 1.1 percent. At the same time, the nation’s carbon intensity is anticipated to increase slightly so that total carbon emissions are projected to rise from 1485 million metric tons

(MtC) in 1998 to 1979 MtC by 2020 for an annual growth rate of 1.3 percent over that same period. However, a close examination for the AEO 2000 forecast indicates that it does not pick up the trends away from a commodity-based to an information-based economy. This can have two different implications. First, as we confirm below, the accelerated growth of electronic commerce may lower the conventional forecast of energy use and resulting carbon emissions. Second, if the nation's decision makers are calibrating a variety of policies to AEO 2000, they may well be designing programs and policies for an economy that may already be significantly different than the conventional forecast, and that may be even more different than is characterized for 2005 and beyond. Hence, the nation's energy and climate policies may be considerably less effective over the longer term.

Adjustments Reflecting the Information Economy

Building on the work of Romm et al (1999), we have decided to test the "energy and carbon significance" of structural changes brought about the growth in the information economy. Specifically, we are examining three changes: (1) reduced production of paper and cement products in the industrial sector; (2) changes related to transportation behavior (vehicle miles traveled); and (3) a further inquiry into the effect of possible structural change. This last effect assumes that the less energy-intensive part of the economy grows more rapidly than the more energy-intensive core sectors of the economy.

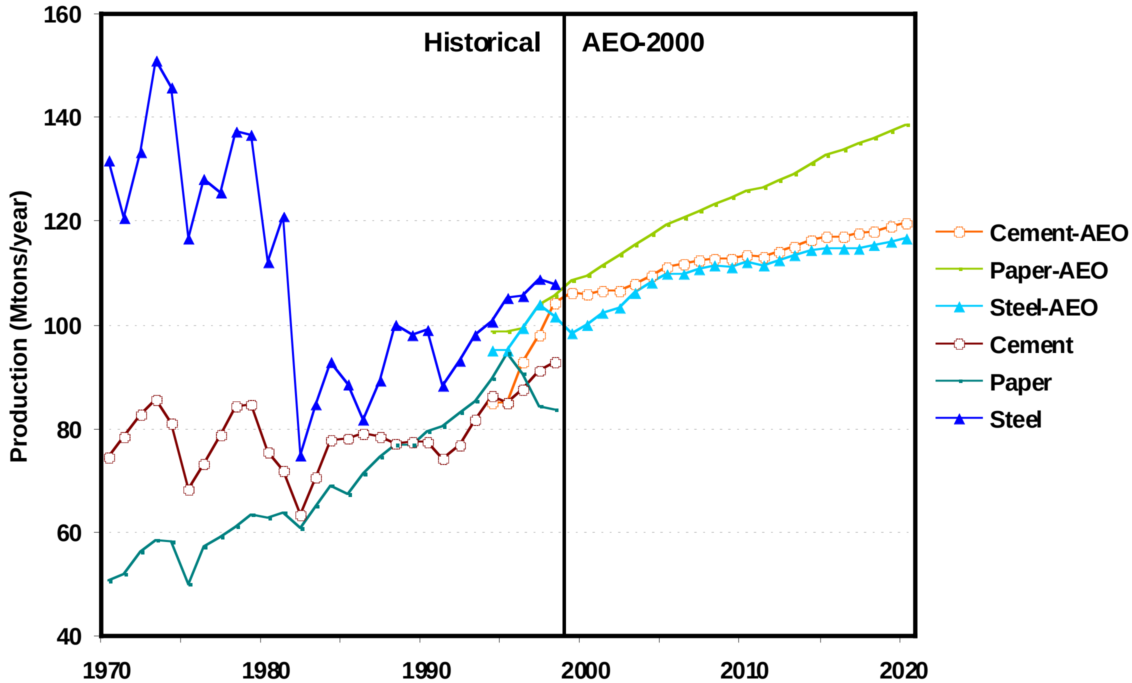
Changes in the Industrial Sector

We develop new scenarios by assessing historic trends for industrial commodities since 1970 with the scenarios developed in the AEO-2000. We focus on aluminum, cement, paper, and steel as these are measured in physical terms in NEMS. All figures are given in short tons.

Total Commodity Production

Comparing historic production of commodities with the assumptions in AEO-2000 shows some serious disconnects for the total production volumes of cement, paper and steel. We did not assess glass or aluminum. Aluminum production in NEMS includes aluminum processing but excludes secondary aluminum production. This makes it impossible to compare to historically available data for primary or total aluminum production. Glass is only a small energy-consuming sector, so we focused on the larger energy consumers. **Figure 1** shows the scenario and historical data. While steel production in 1999 for the AEO-2000 is lower than the actual 1998 production, the 1999 production assumed for paper and cement in AEO-2000 is substantially higher. Table 1 provides an analysis of the material intensity trends as well.

Figure 1. Comparison of historical production trends of cement, paper and steel to the assumed scenario in AEO 2000. Data Sources: LBNL (historical trends), EIA (1999).



Based on the historic trends and other studies we created alternative scenarios. For *paper making* we assume that the trend as reported by Romm et al. (1999), based on the report of the Boston Consulting Group, will continue after 2008. Fitting the paper production reductions estimated in that report with historic data provides an estimate of total volume of paper production of 123 Mtons in 2020, compared to 138 Mtons in the AEO-2000 scenario.

Based on historic trends for *cement making* and the difference in assumed AEO2000 production and actual production in 1998 we assume that the 2020 production will be corrected for the 1998 difference. Hence, 2020 cement production is estimated at 108 Mtons instead of the AEO-2000 forecast of 120 Mtons.

There are several industrial subsectors where data were inclusive or the mechanics of modeling too involved to complete the analysis for this paper. We did not treat trends in the steel and aluminum industries, for these reasons, nor did we treat the potential of dematerialization (due to economic structural changes) of other materials.

The resulting impact of changes in the paper and cement industries on carbon emissions is a reduction of 6 MtC in 2010 and 11 MtC in 2020 compared to AEO 2000, when the product production trends are incorporated into a standalone run of the NEMS industrial model.

Table 1. Comparison of Historic Trends and NEMS AEO 2000 Assumptions for Materials in the Industrial Sector. Trend data and Scenario assumptions are based on physical production data, except for bulk chemicals which is based on economic production data

	HISTORIC TREND DATA						***AEO 2000***		
	Long Term (1970 –1998)			Short Term (1988 – 1998)			1997 - 2020		
	Production (%/year)	Production Per Capita (%/year)	Production per unit GDP (%/year)	Production (%/year)	Production Per Capita (%/year)	Production per unit GDP (%/year)	Production (%/year)	Production Per Capita (%/year)	Production per unit GDP (%/year)
Population	1.0			1.0			0.8		
GDP	3.2			3.0			2.2		
Aluminum	1.7	0.7	-1.5	1.7	0.7	-1.3			
Primary Aluminum	0.1	-0.9	-0.9	-0.6	-1.6	-3.5	0.54	-0.27	-1.7
Cement	0.8	-0.2	-2.3	1.9	0.9	-1.1	0.88	-0.06	-1.35
Steel	-0.7	-1.7	-3.8	0.8	-0.3	-2.2	0.51	-0.003	-1.7
Ammonia	1.3	0.3	-1.8	1.6	0.6	-1.3			
Chlorine	1.0	0.0	-2.1	1.3	0.3	-1.6			
Ethylene	3.9	2.8	2.7	3.4	2.4	0.4			
Bulk Chemicals	1.19			2.56			1.19		

Notes:
Aluminum in the NEMS model is defined as primary aluminum production and aluminum processing, but excludes secondary aluminum production. Most of the energy in the NEMS sector is consumed by primary production, hence we assume that the AEO-2000 trend can best be compared to the trends in primary aluminum production.

Bulk chemicals in the NEMS model is defined as SIC 281, 282, 286 and 287. This is about half of the output of the total chemical industry (SIC 28) expressed as gross output. For comparison we give the physical trend data for the most energy intensive products, i.e. ammonia (SIC 2873), chlorine (SIC 2812) and ethylene (SIC 2869).

Changes in the Transportation Sector

Romm et al. (1999) explored the potential effects of the information economy on personal and business travel, focusing on teleconferencing, telecommuting, e-commerce, and freight transportation. In this initial exploration, we focus solely on vehicle miles traveled per dollar of GDP. In the AEO 2000, the projection is that this ratio will decline by an average 0.45 percent annually between the years 2000 and 2020. However, in the period 1996 through 1999, actual VMT intensity declined by 1.6 percent per year. While this value is too large to anticipate as an on-going trend, following the logic outlined in the Romm et al analysis, we believe it is indicative of changes that are already beginning to occur. As a result, we've adjusted the rate of change to double that suggested in the reference case forecast, which implies a 0.9 percent annual change.

The effect of this trend is to lower VMT by about 9 percent compared to the year 2020 forecast. In other words, instead of VMT growing from 2,511 billion vehicle miles in 2000 to 3,498 billion vehicle miles in 2020, the increase will be to only 3,191 billion vehicle miles under the alternative scenario. The resulting impact on carbon emissions is a reduction of 16 MtC in 2010 and 38 MtC in 2020 in a standalone run of the NEMS transportation module.

We were not able to use the NEMS model to assess changes in freight shipping volumes, but that is an obvious area for future research. The direction of the effects here is less clear than for personal transportation. Increased use of on-line shopping could lead to more airplane and truck traffic if overnight shipping becomes the norm. If shipping by the U.S. Postal Service is more prevalent, the additional energy use would be relatively small. In either case, use of the internet will reduce personal travel to local stores.

Changes in Structural Growth of the Economy

Laitner (2000) completed an analysis that asked the question "how would the nation's energy use grow if the information and communication technology (ICT) sectors grew more rapidly than the balance of the economy?". Drawing from detailed input-output data, he suggested that the ICT sectors were actually 5 times less energy intensive per dollar of economic activity than the balance of the economy. Hence, if these sectors provide a greater level of value added in the years to come, the nation's GDP will grow in a way that uses less energy than perhaps only 5-10 years ago. Laitner determined that if the ICT sectors grew between 8 and 10 percent annually while the total economy grew at a rate of 2.6 percent per year (well above the AEO2000 forecast of 2.2 percent per year), then total energy use in the year 2010 might be 0.7 and 3.2 quads less compared to the reference case projection. In other words, while the faster growth in overall economic activity will tend to increase energy use, the source of that growth — the much less energy intensive ICT sectors — will tend to dampen energy growth to the point where consumption actually drops compared to the reference case.[1] In carbon equivalents, this

[1] There is at least one analysis suggesting that the internet economy would actually increase the nation's energy consumption. However, at EPA's request, researchers at the Lawrence Berkeley National Laboratory (LBNL)

represents a reduction of 11 to 51 MtC. For purposes of this analysis we adopt the average value of 31 MtC.

Net Changes in an Integrated Analysis

The results reported in the previous three subsections total to a combined 2010 saving of 53 MtC. However, these are essentially standalone estimates. By this we mean that there have been no price or income interactions nor supply and demand feedbacks that might otherwise affect these individual totals. We used the NEMS model to assess the effects of an integrated analysis in the results for the industrial and transportation sectors, but we have not yet been able to assess the changes in structural growth endogenously within the NEMS framework.

The industrial and transportation sector effects together save 22 MtC in 2010 and 49 MtC in 2020, based on the standalone runs. The integrated run with both sectors implemented shows savings of 19 MtC in 2010 and 38 MtC in 2020, yielding a reduction of 15 to 20 percent in savings compared to the standalone runs (only 80 to 85 percent of the standalone impact remains after integration).

For the effect of changes in structural growth we estimate the feedback effect using assessments of the feedback, substitution, and rebound effects found in the recent literature. Greening et al (2000) found, for example, that a 10 percent improvement in energy efficiency would lead to a rebound and substitution effect that would leave a net benefit of between 70 and 90 percent of the initially estimated impact. Laitner (2000) provided an example that suggests a 97 percent net impact. For purposes of this exercise, we therefore adopt a conservative estimate of an 80 percent net impact (this estimate also conveniently coincides with the results of the integrating run for the transportation and industrial sectors).

Multiplying the structural growth savings of 31 MtC by 0.80 yields net savings of 25 MtC for this component in 2010. Combined with the 2010 savings of 19 MtC for industrial and transportation in the integrating run, the total savings after accounting for integration would be 44 MtC.

Findings, Discussion, and Further Research

Three small changes have a small but significant impact on the nation's energy use and the resulting carbon emissions. Based upon this initial review, and if the trends described in the text continue to hold, carbon emissions in the year 2010 might be 44 MtC lower than suggested by conventional forecasts. The implication is that instead of carbon emissions rising to 1,790 MtC by 2010, they would increase to only 1,746 MtC, about 2.5 percent lower than otherwise projected. From a policy perspective, a 44 MtC lower base

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evaluated the assumptions behind such a conclusion. The LBNL review found that the analysis overestimated the energy intensity of the internet by a factor of eight. See Koomey et al (1999). At http://enduse.lbl.gov/Projects/InfoTech.html case is more manageable with respect to encouraging policies that support greenhouse gas reductions. Yet this analysis and many others raise more questions than they answer. Some shortcomings of this assessment, in no particular order, are illustrated by the following questions:

(1) The analysis addresses the potential benefits from large-scale structural change, but it does not reflect any significant substitution effects. For example, if households order more groceries, books, clothing and other consumer goods through the growing electronic commerce channels, can we expect their own energy expenditures to be reduced when compared to their previous purchasing patterns?

(2) Would a better definition and measurement of the ICT-sectors, from both an economic and an energy perspective, either weaken or improve the supposed benefits that are described in the scenario analysis above?

(3) What are reasonable estimates of the anticipated ICT-sector growth rates, especially at the sub-sector level of the economy? How will these growth rates influence economic activity in other sectors of the economy?

(4) How will competition and innovation within the ICT-sectors affect productivity gains throughout the nation's economy? How will they impact other inflationary pressures?

(5) Are there other tradeoffs not anticipated by the transition to an information-age economy, including a change in distributional benefits, a change in consumer or producer surpluses, the increased reliance on imported or critical materials, and other environmental and economic impacts?

(6) Will the resources devoted to ICT-infrastructure improvements reduce the opportunities for improvement in other sectors of the economy?

Attempting to answer these and related questions will suggest additional avenues for further research that are both tractable and illuminating. For example, Romm et al. (1999) postulate reductions in commercial building floor area needs from e-commerce and telecommuting that are on the order of 3 Billion square feet by 2010 (about 5% of total commercial floor space). These changes can be relatively easily modeled in the NEMS framework, to assess the implications for energy use and carbon emissions, and they may lead to measurable changes in carbon emissions in our future calculations. We will continue to seek out additional such examples to add to the list of effects we capture in our analysis. Some of these effects may increase carbon emissions, others may decrease emissions, but it is clear that these effects are probably large enough that they can't be ignored.

Conclusions

Our analysis shows small but significant differences in projections from just three modest changes in assumptions about the Internet and/or information-based economy. Other changes that could be important include reduced inventory and warehousing, reduced building construction, changes in other materials utilization, a greater trend toward outsourcing of energy services, and greater improvements in energy efficiency made possible by the new economy. Although the scale of impact for these initially analyzed effects is small, expansion of the scope of inquiry, as suggested by the Romm et al. analysis, may open up new and fruitful areas of research.

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